INDOOR AIR QUALITY ASSESSMENT

Greenwood Elementary School
1030 Main Street
Wakefield, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
January 2003

Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Greenwood Elementary School, 1030 Main Street, Wakefield, Massachusetts. Concerns about poor indoor air quality and possible microbial/mold growth prompted the request.

On October 31, 2002, a visit was made to this school by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Peter Grey, Director of the Wakefield Health Department during the assessment.

The school is a two-story brick structure originally constructed in 1897. The building underwent renovation in 1924. Windows are openable throughout the building.

An environmental consulting firm, ATC Associates, Inc. (ATC), was retained by the Wakefield School Department to conduct an indoor air quality/microbial investigation of the school. Based on the results of this investigation, ATC staff made the following recommendations:

1. Restore and update the existing mechanical ventilation if possible, if not the system should be sealed.
2. Keep window wells free from accumulated leaves and debris.
3. Restore function to restroom exhaust vents.
4. Fix leaks in the boiler room and discard all water damaged cardboard.
5. Consider replacing dry erase board markers with low odor/water based markers.

In addition, ATC conducted airborne microbial sampling and determined that all air samples collected indicated low fungal levels that were below outside samples and airborne bacterial levels that were also similar to those measured outside (ATC, 2002).

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The school has a student population of 220 and a staff of approximately 30. The tests were taken during normal operations at the school. Test results appear in Tables 1-3.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in eleven out of twenty three areas surveyed, indicating a ventilation problem in the building. Please note that rooms with carbon dioxide levels below 800 ppm either were unoccupied or had windows open. The ventilation system in the building was not operating during the evaluation. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows are closed, due to the configuration and condition of the ventilation system.

Fresh air was originally provided by an air handling unit (AHU) located in a large room on the ground floor that is connected to ductwork leading to air diffusers. Fresh air is drawn into the building through a louvered vent in the basement (see Picture 1). Air is drawn through heating elements into a fan unit that distributes the air via wall mounted fresh air grilles in classrooms (see Pictures 2-4). Classroom fresh air supply grilles are connected to the fan unit by ductwork located in the basement. This ventilation system appears to have been abandoned as part of an energy conservation project based on the following observations:

1. A number of fresh air intakes were sealed with plywood (see Picture 5).
2. The fresh air intakes on the exterior wall as well as for the AHU were shut and actuators, which controlled airflow, were removed (see Pictures 1 & 6).
3. The fan belt connected to the motor that drives the fan unit was removed (Picture 7).

These alterations have resulted in open windows serving as the sole source of fresh air in the building.

Pressurization created by the original fresh air supply system also provided classroom exhaust ventilation. Each classroom contains an exhaust vent located at floor level that is connected by ventilation shafts to the basement heating elements. A number of these vents were obstructed by cabinets, bookcases and other items. As the heating elements draw air into the ducts, return air is drawn from the basement exhaust ventilation shafts. Negative pressure is created in these shafts, which in turn draw air into the exhaust vents of each classroom. The draw of air into these vents is controlled by a draw chain pulley system. Because this system has been abandoned, no means of mechanical supply or exhaust ventilation exists.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Please note that the ventilation systems, in their condition at the time of the assessment, cannot be balanced.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health

Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings ranged from 71^{o} F to 79^{o} F during the assessment, which were very close to the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 19 to 30 percent, which was below the BEHA recommended comfort range in all areas surveyed. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment.

Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Anecdotal reports made by building occupants identified concerns about the existence of a mold odor in the south stairwell of the building near the main office. These odors were traced to the boy's restroom located at the bottom of the stairs. Wakefield School personnel have made a number of attempts to identify the origin of this odor. The restroom contains an exhaust ventilation system (see Picture 8). The ductwork of this system roughly corresponds to a rooftop general exhaust airshaft (see Picture 9). A separate duct that is connected to a turbine fan exists above the roof over this exhaust airshaft. This type of fan was used to provide exhaust ventilation. The turbine is designed to spin in the wind, which rotates a fan inside the duct. The turbine fan of this vent was frozen in place, therefore creating no draw of air from the boy's ground floor restroom. The urinals inside the restroom are installed on a wall that serves as a large exhaust vent duct that is connected to the exhaust system. Within this enclosure is an uncapped sewer pipe (see Picture 10), which was likely in this condition when the exhaust vent system was built. If the turbine exhaust vent were spinning, the draw of odor from this open pipe would be drawn into the duct and ejected from the building through the vent. With the turbine frozen, odors from this pipe can enter the restroom through the exhaust vent grilles located above the urinals.

In order to explain how odors/particulates from the open pipe in the boy's restroom can migrate into occupied areas on upper floors, the following concepts must be understood:

- Heated air in the basement will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As the heated air rises, negative pressure is created, which draws cold air to the heat source.
- Airflow created by the stack effect, drafts or mechanical ventilation can draw odors into the air stream (i.e. from the basement).
- The opening of the restroom door to the basement at the base to the stairwell can provide a pathway for air to travel from the basement to the upper floors.

Each of these concepts has an influence on the movement of basement odors and/or particulates up the stairwell. In order to control odors from this restroom, capping of all open sewer pipes and reestablishment of the operation of the turbine exhaust ventilation system must be done.

Shrubbery exists in close proximity to the foundation walls (see Picture 11). The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek, J. & Brennan, T.; 2001).

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. The abandoned ventilation system can also serve as a pathway for basement particulates and odors to migrate into occupied areas of the building. Holes in walls and ceilings may also serve as pathways for particulates. In general, cold air migrates to areas with heated air, thereby creating drafts. The temperature in the heating coil room will generally be lower than the occupied areas of classrooms, therefore colder basement air will move to classrooms via the vent system if means of access (holes, open access doors) exist in the ductwork. In this instance, pathways for basement air, odors and particulate matter exist. Also observed were open utility holes and a corroded access plate to the crawlspace in the boy's restroom (see Picture 12). These breaches can also serve as additional sources of particulates and odors.

A number of classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). Dry erase board markers and cleaners contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

In an effort to reduce noise from sliding chairs, tennis balls are sliced open and placed on chair legs (see Picture 13). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and to off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1998).

The photocopier room has no local exhaust ventilation to help reduce excess heat and odors. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, D., 1992).

A number of classrooms contained upholstered furniture (see Picture 14). Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, M.A., 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis or every six months if dusty conditions exist outdoors (IICR, 2000).

Conclusions/Recommendations

The abandonment/alteration of the original ventilation system and its components has essentially removed any means to provide mechanical ventilation for the building. This minimization of airflow into the building can result in environmental pollutants concentrating in occupied areas due to the lack of dilution and/or removal by the ventilation system.

1. Seal all open pipes in the space behind the urinals.
2. Repair the turbine vent on the roof. Consider replacing the turbine vent with a motorized exhaust ventilation fans to remove odors from the basement boy's restroom.
3. As recommended by ATC, if original mechanical ventilation systems are not fully restored, ensure abandoned exhaust and supply vents are properly sealed in classrooms, the basement and on the roof to eliminate pathways for movement of odors and particulates into occupied areas.
4. Consult a ventilation engineer to determine whether the building can be retrofitted with a modern mechanical ventilation system.
5. Use open windows and hallway doors to enhance airflow during warm weather. Be sure to close windows and doors at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a floor without interfering with the natural, internal airflow pattern of the building. To aid cross ventilation, open hallway doors in areas with inoperable transoms.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high

efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

7. Move foliage to no less than five feet from the foundation.
8. Consider discontinue the use of tennis balls on chairs to prevent latex dust generation.
9. Seal utility holes and repair/replace the corroded access plate in the boy’s restroom, to prevent the egress of dirt, dust and particulate matter into occupied areas.
10. Consider installing local exhaust ventilation in photocopier room.

References

ATC. 2002. Report of Indoor Air Quality Site Visit, Greenwood School, Wakefield, MA. Dated October 23, 2001. ATC Associates, Inc., Woburn, MA. ATC Associates Project No.: 60-20290.0004.

Berry, M.A. 1994. *Protecting the Built Environment: Cleaning for Health,* Michael A. Berry, Chapel Hill, NC.

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

IICR. 2000. IICR S001 Reference Guideline for Professional On-Location Cleaning of Textile Floor Covering Materials Institute of Inspection, Cleaning and Restoration Certification. Institute of Inspection Cleaning and Restoration, Vancouver, WA.

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

NIOSH. 1998. Latex Allergy A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC. http://www.sbaa.org/html/sbaa_mlatex.html

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

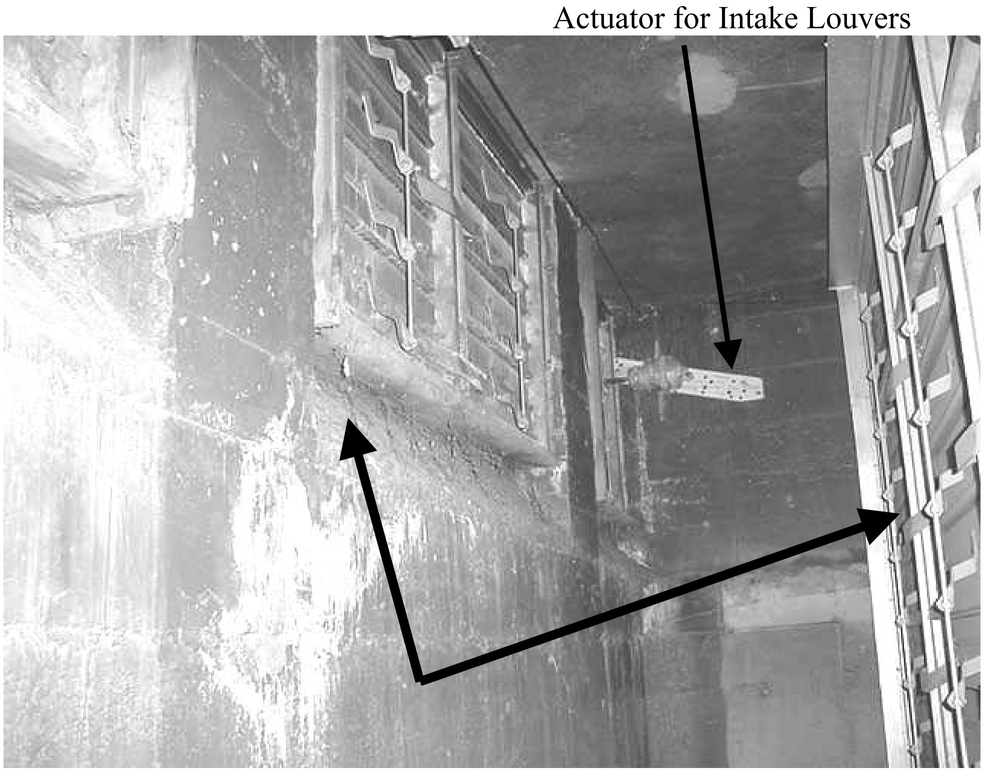
Schmidt Etkin, D. 1992. Office Furnishings/Equipment & IAQ Health Impacts, Prevention & Mitigation. Cutter Information Corporation, Indoor Air Quality Update, Arlington, MA.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation. Bellwood, IL.

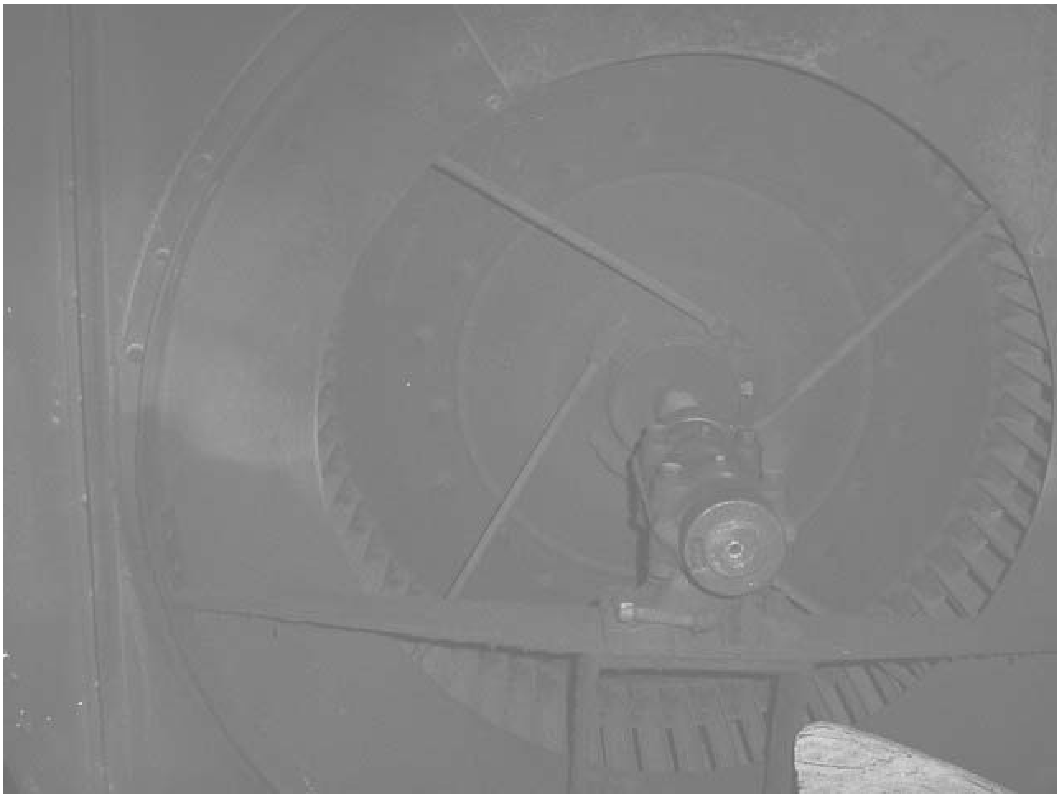
US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Research Triangle Park, NC. ECAO-R-0315. January 1992.

Picture 1



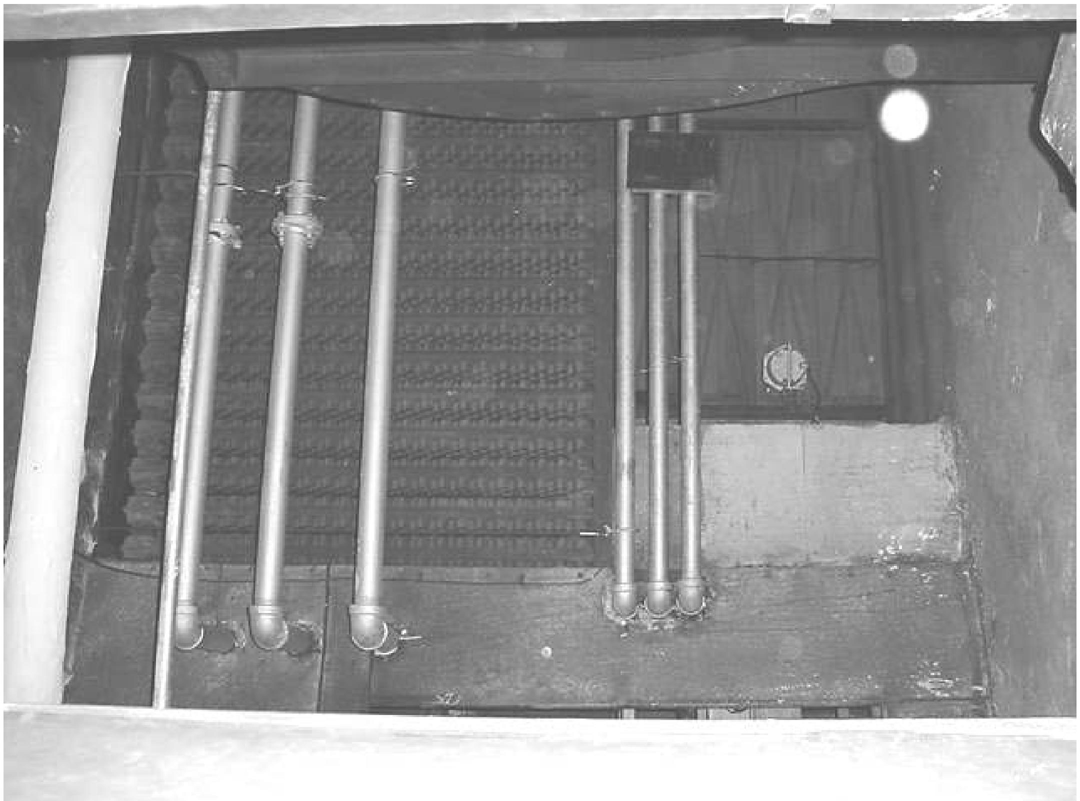
Fresh Air Intake on Exterior Wall (On Left) and Intake for AHU (On Right)

Picture 2



Large Ventilation Fan In Basement

Picture 3



View of Heating Elements and Steam Pipes Taken “Up” The Ventilation Shaft in the Basement

Picture 4

Grated Supply Vent for Ventilation System

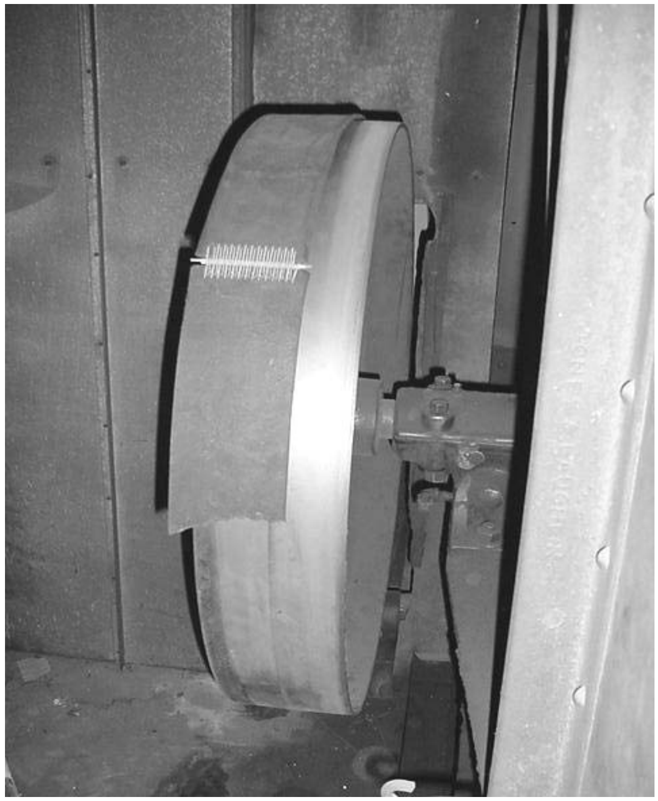
Picture 5

Classroom Supply Vent Sealed With Plywood

Picture 6

AHU Air Intake Shut

Picture 7



Remnants of Fan Belt on Mechanical Ventilation System Flywheel

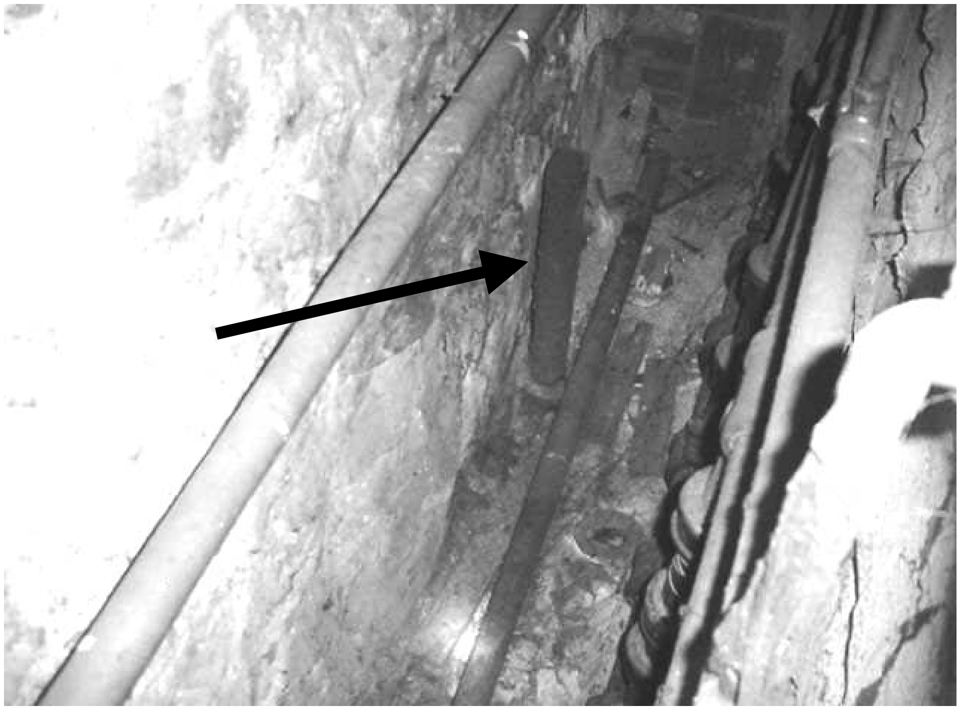
Picture 8

Exhaust Vent Duct for Restroom

Picture 9

Turbine Fan for Restroom Exhaust Vent Picture 9

Picture 10

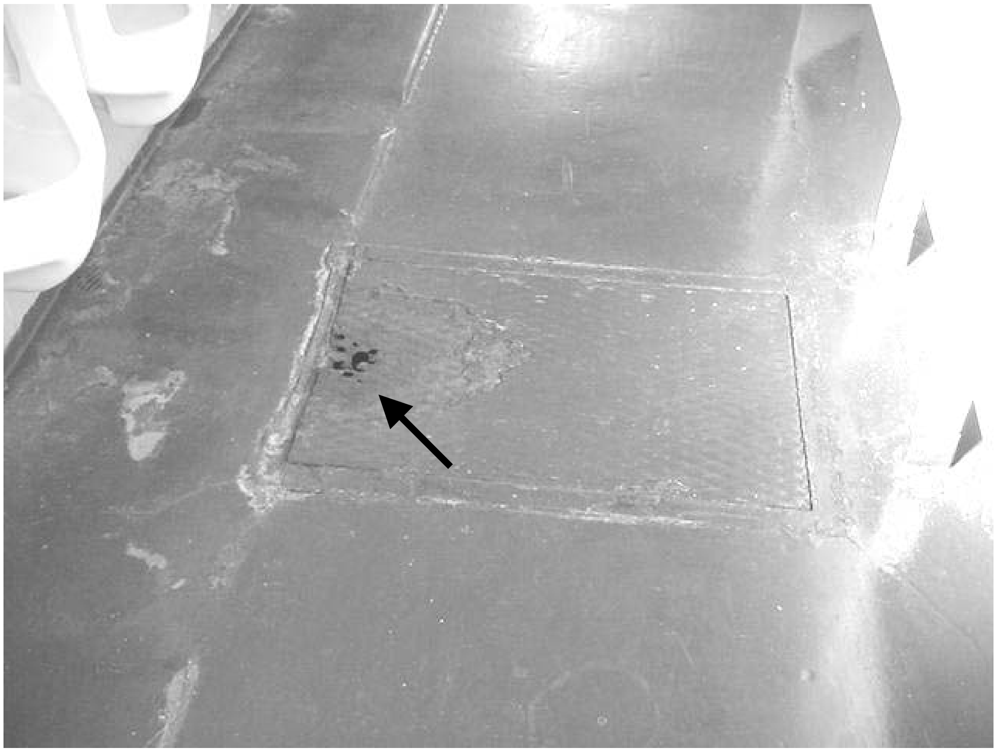


Open Pipe within Exhaust Vent Duct for Restroom

Picture 11

Shrubbery in Close Proximity to the Foundation Wall

Picture 12



Corroded Hole in Crawlspace Access Panel in Restroom

Picture 13

Tennis Balls on Chairs

Picture 14

Upholstered Furniture in Classrooms

TABLE 1

Indoor Air Test Results –Wakefield – Greenwood Elementary School **October 31, 2002**

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Background	325	53	26					
Room 18	942	76	25	20	Y	Y	Y	Window open, intake and exhaust off
Room 9	1095	75	25	8	Y	Y	Y	Window open
Gym	847	75	26	504+	Y	Y	Y	Intake and exhaust off
Room 8	591	72	19	12	Y	Y	Y	Window open, intake off, blocked with plywood, exhaust off, blocked with table
Room 7	910	73	24	13	Y	Y	Y	Window open, intake off, exhaust off and blocked with beanbag
Room 6	775	75	28	0	Y	Y	Y	
Room 5	588	75	22	22	Y	Y	Y	Window and door open, tennis balls on chair/table legs
Room 4	552	74	22	5	Y	Y	Y	Window open
Room 3	770	73	25	6	Y	Y	Y	Tennis balls on chair/table legs
Teachers Room	641	74	22	1	Y	Y	Y	Window and door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results –Wakefield – Greenwood Elementary School **October 31, 2002**

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Main Office		73	21	3	Y	N	N	Window and door open
Library	697	71	32	7	Y	Y		4 computers
Art Room	688	71	27	0	Y	N	Y	
Music Room	453	71	25	7	Y	Y	Y	Window and door open, dry erase board, utility hole, intake off, exhaust blocked
Room 110	1594	75	29	0	Y	Y	Y	Door open, intake blocked with paper, exhaust blocked with chair, tennis balls on chair/table legs
Room 113	1057	76	26	4	Y	N	N	Dry erase board
Room 12	720	77	23	0	Y	Y	Y	Window open, intake off Exhaust off and blocked with shelf, tennis balls on chair/table legs
Room 13	1565	76	30	24	Y	Y	Y	Door open, intake off/covered with plywood, exhaust off, tennis balls on chair/table legs

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results –Wakefield – Greenwood Elementary School October 31, 2002

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 14	607	76	20	0	Y	Y	Y	Window and door open, dry erase board, intake and exhaust off, tennis balls on chair/table legs
Room 15A	920	77	25	0	Y	N	Y	Exhaust off
Room 15B	876	79	30	0	Y	Y	N	
Room 16	951	76	25	22	Y	Y	Y	Intake and exhaust off blocked by cabinet, tennis balls on chair/table legs
Room 17	951	76	25	22	Y	Y	Y	Intake and exhaust off, dry erase board, tennis balls on chair/table legs, hole in closet
Photocopier	--	--	--	--	Y	N	N	Window open, photocopier/rizograph
After School Room	575	71	23	0	Y	N	N	Hole in ceiling

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%